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AUTHOR Wang, Jianjun
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ABSTRACT

This paper traces the evolution of school physics in China and elaborates on the current situation, ongoing experiments, and problems of school physics in terms of the historical, cultural, political, and social contexts in China. School physics as a major subject was imported into China almost wholesale by the end of the 19th century. Nonetheless, physics was technically procrastinated due to the fact that very few physics terms existed in classical Chinese literature. The first significant impetus toward more emphasis of physics came from a May 4 Movement in 1919 when thousands of Peking students marched in protest against Japan. As the movement spread, many Chinese youth went to the West to study physics, and later became the first generation physicists in China. The China Physics Society was soon established, and the mission of converting physics terms into Chinese was systematically carried out. A second movement, the New Culture Movement, originating from the May 4 Movement, was strengthened through the era of the Nationalist government (1920s-30s). This movement made physics more accessible to the general public, and differentiated physicists from classical scholars. During the Mao regime, school physics was imported from Russia because of China's isolation from the West in 1949. Later, during the Great Leap Forward movement (1958-1960) school physics was simplified to cover readily applicable aspects of the knowledge base. By the end of the Cultural Revolution in 1976, the contents of physics were shrunk into only four components: the steam engine, the internal combustion engine, the electric motor, and the pump. Physics instruction is currently driven at the secondary level by the college entrance examination, and at the tertiary level by the market economy. Ongoing experiments are guided by societal needs and the government's policy in education. Debate regarding the government's role in education was silenced after the Tiananmen Square event, but discontent in the physics society stays high. Contains 46 references. (JRH)

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Evolution of School Phyiscs in the People's Republic of China

Jianjun Wang
Department of Teacher Education
School of Education
California State University
Bakersfield, CA 93311-1099

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RUNNING HEAD: SCHOOL PHYSICS IN CHINA

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Evolution of School Phyiscs in the People's Republic of China

Abstract

School physics was transplanted from the west into China by the end of the 19th century. The evolution of Chinese school physics was briefly reviewed in this paper, and in-depth discussions about the current situation, ongoing experiments, and problems of school physics were presented in terms of the historical, cultural, political, social contexts in China.

Evolution of School Phyiscs in the People's Republic of China

School physics as a major subject was imported into China almost wholesale by the end of the 19th century. The naturalization of school physics in China throughout the 20th century has been one of the most interesting topics attracting many sinologists and science educators in the west (e.g., Cross & Price, 1988; Manos, 1990; Murray, 1992; Swetz, 1980; Wellington, 1992). Cheng (1984) observed:

> It always surprises foreigners that physics is given an extraordinary emphasis in China. In the order of importance, physics comes fourth behind language (Chinese), mathematics and foreign language (in most cases English). Even in the reformed curriculum, it is noticeable that physics is taught across the streams. Physics is also a basic subject in many non-science university faculties. (p. 116)

How could an imported subject gain such an extraordinary emphasis in the oriental educational system? What are the current situations and ongoing experiments in Chinese school physics? What are the problems and controversies raised in Chinese society and research associations about physics education? These questions are discussed in this paper in terms of the historical, cultural, political, and social context in China.

The Import of School Physics

Since the middle of the 19th century, Ch'ing dynasty, the last feudal empire in Chinese history, was forced to sign a set of "open-door" treaties with the west. Reardon-Anderson (1991) pointed out:

> Chinese "self-strengtheners" established arsenals, shipyards, schools and translation bureaus and sent students abroad, all for the ships, guns, and secrets of making them, needed to protect the empire against rebellion at home and invasion from abroad. But this is as far as the Ch'ing dynasty would go. The dominant, conservative forces in Peking rebuffed attempts to broaden the curriculum of civil service exams, by which officials were chosen, or the scope of industrialization, which would have created greater demand

for new knowledge and skills. (p 8)

Apparently, at the time physics was introduced into China along with other science subjects, the feudal government intended to degrade its importance in Chinese schools. At the same time, physics was well developed in the west, and classical physics was taught systematically in western schools. Even though modern physics, such as quantum mechanics and special relativity, was yet to be developed, the then-existing knowledge of classical physics was widely used in defence technology of the nineteenth century. It was the value of technological application that led the Chinese government acknowledge and embrace the existence of physics.

Nonetheless, import of physics was technically procrastinated due to the fact that "very few physics terms existed in classical Chinese literature" (Zhao, 1990). Reardon-Anderson (1990) wrote:

> What was needed was a fresh neologism, free from the established connotations, that could stand for the new idea. The Japanese had come to grip with this problem several decades before it was appreciated in China. Some Japanese, influenced by the same neo-Confucian texts that guided scholars on the mainland, chose the terms ***kakubutsu*** [***ko-wu***] and ***kakuchi*** [***ko-chih***] to describe "science," and in later years "physics". (p.85)

The issue of nomenclature signified the imported feature of physics. Unlike other classic subjects in Chinese history, physics had little contribution to the enhancement of self-esteem in Chinese culture. During this historical period, China sufferred a number of defeats against the West. Even most "self-strengtheners" at that time would not endorse physics as a major subject, but rather treated it as minor techniques for application purposes. The reluctance of Chinese authority was grounded on the age-old ideology in which too much

emphasis on non-traditional knowledge might yield to criticism of "counting classical events while forgetting ancestors" (*shudianwanzhu*).

The first significant impetus toward more emphasis of physics came from a May 4th Movement in 1919 when thousands of Peking students marched in protest against Japan. The movement was provoked by the 1919 Versailles Treaty in which the Allies paid Japan with Chinese territory for its World War I aid (Parker & Parker, 1986). It was this movement that awakened the Chinese public and proclaimed the needs of "Mr. Science" and "Mr. Democracy". As the movement spread, many Chinese youth went to the West to study physics, and later became the first generation of physicists in China. The China Physics Society was soon established, and the mission of converting physics terms into Chinese was systematically carried out. Nomenclature of classical physics ended in the early 1950s, which has greatly facilitated naturalization of physics education in China. Zhao (1990) wrote:

> The use of auxiliary "international" languages for science instruction is a truly knotty problem common to almost all the developing countries. Before 1949, physics was taught in China either through a kind of mishmash of English terminology and spoken Chinese, or completely in English (usually in missionary schools). Within a few years of the foundation of the People's Republic, lecturers and textbooks went over to full use of the mother tongue at all levels. Owing to the effort of Chinese physicists in this century to assimilate modern physics terminology into standard Chinese, no serious obstacles to sinicization have been encountered. On the contrary, physics education in China has benefited remarkably from this regime of learning in the mother tongue, especially at lower education level, and in communicating physics to the general public. (p. 452)

During the Nationalist period in 1920s - 1940s, school education in China was influenced by the New Culture Movement and the National Defence Education Movement. The New Culture Movement originated from the May 4 Movement, and was strengthened throughout the golden era of the Nationalist government (1920s-30s). The focus of this

movement was two-fold, advocating non-classical style of written Chinese and repudiating Confucianism in education.

Physics is a subject based on experiments, rather than didactic doctrine. Thus, students who study physics are much less bookish than those majoring in classical literature. Had physics been explained in classical Chinese, students would have been distracted in a tedious language decoding process, which no doubt could have been an extra burden to physics education. In reality, classical Chinese was too outdated, and used only in written communications among a small group of Confucian intellectuals. The thorough reform of classical Chinese in the New Culture Movement made physics more accessible to the general public, and differentiated physicists from classic scholars in terms of the language style.

On the other hand, the positive effect of renouncing Confucianism is less clear to many science educators around the world. Zhu (1992) maintained: "Anyone who wishes to investigate traditional Chinese education must take a serious look at the influence of Confucius over the lengthy period of Chinese educational history" (p. 3). Indeed, the Confucian school upheld strong family and social commitment in education. But the emphasis of Confucian education was never placed upon physics or related natural science subjects. In fact, many historians believed that Confucianism suppressed the potential development of modern science in ancient China (Needham, 1969; Qian, 1985). As a result of challenging the predominant position of Confucianism in Chinese schools, the New Cultural Movement further promoted the importance of physics and other natural sciences. In essence, this movement had a profound effect similar to that of Renaissance in the West.

The National Defense Education Movement (1930s-40s) was launched by many

Nationalist intellectuals during the anti-Japanese war in World War II. Because physics had extensive applications in military industries, physics education became vital to the national defence, and many patriotic students chose to major in physics during the war-time. In spite of the difficult teaching conditions and disastrous economic situation caused by the Japanese invasion, most Chinese physicists trained in the West during the 1920s and 1930s went back to China to assume faculty positions in school physics. Thus, as the National Defence Education Movement swept throughout many national schools and universities, students were well motivated, and the quality of physics education was enhanced. It should be noted that a few excellent students graduated in this period from the once-famous South-Western United University in China, such as C. N. Yang, T. D. Lee, and Z. Z. Ding, who won the Nobel prize in physics for their subsequent studies in the United States. When recalling their learning experiences, they all appreciated the war-time training in fundamental physics from the cogent programs in Chinese schools.

In the middle of the twentieth century, China experienced an abrupt power transition between the Nationalist and Communist parties. Isolated from the West in 1949, China was forced to model its educational system after the former Soviet Union. Henceforth, weakness of the Soviet inflexible system plus the ideological conflict between China and the Soviet Union caused relentless adjustment in Chinese school physics.

In the early 1950s, the honeymoon with the Soviet Union and eastern Europe reshaped Chinese physics education. Russians were admired as the "older brother" in China. Most physics textbooks were translated from the Soviet Union. Russian teaching methods were extensively adopted in Chinese schools. Compared with most textbooks in the West, Russian

physics was more cogent and theoretical. The national unified curriculum modeled after the Russian curriculum served the purpose of standardizing physics education over the "New China". Considering the fact that many intellectuals fled to Taiwan before the mainland was taken over by the Communists, the national curriculum had a positive effect in maintaining the quality of standards for physics education. At the same time, many Chinese physicists studying or working abroad responded to the government's call for national reconstruction, and returned home to fill most of the vacancies left by the Nationalist intellectuals. In this period, the majority of Chinese educators were quite motivated, and the public illiteracy rate was reduced dramatically. Further improvement of the imported Russian system, such as too narrow classification of school majors, and national job assignment programs, could have been made had school education continued to serve economic development.

Unfortunately, the then Chinese leader, Mao Tsedong, had no realistic plan to reconstruct China. He was more interested in man-made "class struggle" to fortify his political position against "revisionists" in the Soviet Union. Since the late 1950s, Mao's worship steadily escalated, and eventually ended in the disastrous Cultural Revolution. Meanwhile, physics education was also brutally interfered by many outrageous slogans, and full recovery did not occur until the death of Mao in 1976.

According to Mao, "Education must serve proletarian politics and be combined with productive labor" (Swetz, 1979). In practice, physics education was under tremendous political pressure toward reducing the knowledge base. Under the Maoist slogan, "red and expert", physics classes were designed to connect school and productive labor, and to enhance students' "class consciousness" through interactions with workers, peasants, and soldiers.

Evidently, "class consciousness" had nothing to do with genuine physics instruction, and the dismantling of physics into isolated application parts could seriously impede the proper preparation of qualified "experts". Therefore, whenever Mao called for changes in education, the quality of school physics deteriorated.

The school physics imported from Russia was first attacked in the late 1950s for its "expert"-orientation. During the Great Leap Forward movement (1958-1960) launched by Mao, school physics was simplified to cover readily applicable aspects of the knowledge base. Attempts to restore school order were made by the majority of patriotic intellectuals at the end of the Great Leap Forward movement. However, due to the overwhelming worship of Mao, the effort of recovery did not result in substantial improvement of school physics, and the failure of the Great Leap Forward only caused Mao's temporary retreat at the beginning of the 1960s. Swetz (1973) recollected:

> By the spring of 1963, Chinese education had entered into a phase of increased political awareness. Required student productive labor was used as a means of raising class consciousness and renewed official encouragement for peasant-worker spare-time education promoted proletarianism. Early in 1964, Mao reiterated the need for educational reform. Specifically, he urged:
> 1) The total period of schooling be shortened
> 2) Curricula be reduced by half
> 3) The stress on examinations be discontinued
> Further, he cautioned that academic demands were becoming excessively over-burdening for students. (p. 156-157)

The briefly installed school order during Mao's temporary retreat was soon broken in the subsequent Cultural Revolution. Systematic physics instruction was categorized as a residual of "Soviet Revisionism", and the national physics curriculum was completely abandoned. In this period, physics was first combined with chemistry to form a new subject

named "basic knowledge in industry". The textbook was edited at local provincial levels with extensive quotations of Mao's works. In the early 1970s, physics retained its subject identity in Chinese schools, but contents of the textbooks still varied across provinces, cities, and autonomous regions. By the end of the Cultural Revolution in 1976, the contents of physics were shrunk into only four components, the steam engine, the internal combustion engine, the electric motor, and the pump, in most regions (Amidei, 1980).

During the same period, no qualified physicists were trained in tertiary education. Most high school graduates were sent to the countryside to obtain "re-education" from illiterate peasants. The re-education took at least two years, and no systematic study of science was encouraged. Promotion or college entrance was based upon political consciousness, rather than academic competency. Students who entered tertiary education through peer-recommendation either completely forgot or never mastered the fundamental knowledge base in secondary education. There were no regorous examinations in colleges or universities, and students were encouraged to follow the drastic example of Tiensheng Zhang, a student who was praised by Mao for not being able to answer any questions in an academic exam (Li, 1990)! In spite of all these outrageous measures, physics enjoyed slightly better treatment in tertiary education because of its content and applications in many national projects, including improvement of missiles and atomic bombs. Students majoring in theoretical physics, for instance, were given four years of training while other programs were reduced to three years. Regardless of these incentives, it was still impossible to provide quality physics education in the non-academic climate to under-prepared students. Schmuckler, Wei and Zheng (1990) commented:

> As a result of the Cultural Revolution (1965 to 1976) which closed virtually all of the schools for almost ten years, there existed by the late 1970s a three-level stratification of faculty according to age and academic preparation: (a) elderly faculty members whose numbers had been severely decimated by deaths during the Cultural Revolution, due to natural causes, suicides and severe working conditions in the countryside, (b) middle-aged faculty members who were near or at the beginning of their academic careers when the Cultural Revolution began, and (c) the very young and recent graduates, being taught by the other two under-prepared groups. The first group's knowledge was dated, and the second group's education had been cut off early in their careers. According to the educational leaders, China needed and welcomed assistance from the outside. (p. 80)

Shortly after the death of Mao, Deng Xiaoping re-assumed governmental power, and started an arduous modernization movement. He lost no time in re-installing the educational system destroyed by Mao in the Cultural Revolution. The first change he made was a re-introduction of national college and university entrance examination. He announced: "From now on, not only secondary schools and colleges must make an overall examination of the applicants in respect to their moral, intellectual and physical levels and enroll only those who are outstanding; all departments should gradually do likewise and, in increasing their work force, give priority to those who are outstanding" (Deng, 1978; p. 10). In his view, "Examinations are an important method of checking on studies and on the efficacy of teaching, just as checking the quality of products is a necessary system for ensuring factory standards" (Deng, 1978; p. 7). The new policy was quickly implemented across the country. Swetz and Yu (1979) reported:

> Perhaps the most dramatic and concrete testimony to the new educational polices of the country has been the reinstatement of university entrance examinations. ... From November 28 to December 25, 1977, some 5.7 million candidates sat for this first series of resurrected examinations. (p. 23)

In response to these dramatic changes, unified physics textbooks at secondary level

were developed and adopted throughout the nation in the 1980s. Abelson (1979) observed. "Today, training in the middle schools is heavily oriented toward the natural sciences and mathematics. The best students want to become physicists" (p. 203). Amidei (1980) concurred:

> Physics is "king" among middle school sciences, clearly enjoying the highest status. ... Only mathematics and Chinese language get more time and attention. Grade 7 physics seems to be much like a seventh-grade physical science course in the U.S. By grade 10, students have studied mechanics, fluid dynamics, gravity, etc., and the level seems to be that of a non-calculus physics course for pre-medical college students. (p. 21)

Re-emergence of the important position for school physics largely resulted from the arduous competition in the college entrance examination. China was a developing country, and only a small proportion of high school graduates could be accommodated and admitted to tertiary education. Accordingly, many well-educated high school graduates were turned down in the entrance examination. From the view of test competition, physics is one of the most difficult subjects in secondary education. Thus, many students who were equally talented in other areas were eventually differentiated based on the score of physics. As the pressure of examination increased, more attention was paid to school physics in secondary education.

Emphasis on physics teaching was also reinforced by the enhancement of professional autonomy among school teachers in the Deng Xiaoping era. Although the "red" and "expert" criteria are still advocated by the government, few educators would support brutal interference in physics education through political movements. Mao's directions disappeared from physics textbooks. The only political element emphasized in physics teaching is cultivation of dialectical materialistic world-view (Zhang & Qian, 1979). According to

Seybolt (1980), "The dialectical-materialist world view is essentially a scientific methodology" (p. v). The traditional dilemma of balance between theory and practice has been settled in physics education with more emphasis on laboratory experimentation. Seybolt (1980) reported:

> The relationship between theory and practice, learning and production, is now to be handled mainly through laboratory experimentation, which has been greatly increased in the new curriculum, and through certain typical examples of production technique in the readings. (p. v)

Despite the existence of debates on the guiding role of the dialectical materialist world view (Williams, 1990), physics education in current Chinese schools is much more professional than ever before. This, in part, is due to the lesson taken by Chinese educators from the Mao era, in which the nightmare of "class struggle" still bothers many intellectuals. As the Chinese economy keeps growing throughout the Deng Xiaoping era, the major objective of physics education has been shifted from purely serving proletarian politics to broadly facilitating modernization of the country.

The Current Situation of Chinese School Physics

Presently, physics is one of the major subjects in Chinese school system. Under competition of a global economy, China was forced to improve the quality of education, especially in areas of mathematics and science. Meanwhile, the government won't support the improvement at a substantial cost of political stability in China. The concern of political security has more impact on physics education than on any other school subjects. Fang (1990) pointed out:

Physics is not a doctrine. Even in the first course in physics, we discuss the problem

> of dealing with experimental errors, and we teach our students that physics is always changing, that old theories are replaced by new ones. It would be futile to try to conceal errors in physics, for physics is not a field in which making a mistake, or pointing out someone else's error, is a capital offense. There, it is impossible to have a student who keeps an open mind about physical problems but unquestioningly worships a dictator. (p. 809)

As a pre-cautionary measure, the government has set the integration of patriotism and dialectical-materialism in physics teaching as one of the major goals for physics education. The government maintains that this goal can stimulate students' interest in physics and enhance their scientific attitudes.

In essence, however, physics is a branch of natural sciences. Thus, contents of school physics are more or less comparable across the world. Many researchers wished to establish the equivalency of physics curriculum between China and the West. Shi (1983) reported: "The six years of middle school education in China corresponds to the six years of secondary education in the U.S." (p. 1011); "The subject matter in General Physics is similar to that in the American college with an exposition of the concepts of physics together with the application of analytic methods and quantitative manipulations" (p. 1012); and "The level of the theoretical physics courses is similar to that in Feynman's Lectures on Physics" (p. 1012). Murray (1992) maintained: "My conclusion was that undergraduate physics laboratory facilities in China--if not as well appointed--were not significantly different from those in the United States" (p.210). Cheng (1984) made a similar comparison in terms of the British system. He wrote:

> If we look at the standard of the intended physics syllabuses and compare them with their British counterparts, we arrive at the following broad conclusions:
> The Chinese junior-middle syllabus is lower than the GCE O-level, but with greater emphasis on daily applications.

> The Chinese senior-middle requirement is lower than the GCE A-level in the scope of study, in its mathematical requirement and in the emphasis on practical work. The Chinese "general physics" studied at university first- and second-year level is somewhat higher than the GCE A-level, but the former is much more academically structured. (p. 116)

It should be noted that the national curriculum involved in these comparisons was implemented under different financial conditions in China. As a developing country, only 2.7 percent of the Chinese Gross National Product was spent on education. Hence, many secondary schools do not have well-equipped physics laboratories for classroom demonstrations and student experiments. Consequently, Chinese students' experimental skills are generally weaker than their counterparts in the West. Shi (1983) assessed:

> The depth of coverage of physics courses in middle schools and colleges are quite good, and students are also well drilled in problem solving. However, the teaching may lack breadth in associating physical laws with everyday physical phenomena. As a consequence the students are not well trained in extending their knowledge to practical matters. (p. 1014)

Swetz (1980) depicted some in-depth reasons behind the current situation:

> China is a developing country and as such the balance between "theory and practice" in the teaching of physics warrants critical consideration. If the subject becomes too theoretical, its applications are divorced from the realities of Chinese life. If on the other hand it becomes overly practical, it frustrates the drive for rapid modernization and industrialization. Chinese physics educators are well aware of the trends in teaching of their subject outside of China but must proceed cautiously in adopting any of these reforms as memories of the last period of radical education revision, the cultural Revolution, are still quite fresh in their minds. (p. 366)

In contemporary China, physics curricula are structured in a spiral mode. This general mode is based on the fact that to most young pupils, much of the logic reasoning in physics is not easy to digest in one stroke, and in-depth understanding requires solid mathematical background and lab experience. Since no knowledge of equations has been covered in

mathematics classes before the seventh grade, physics cannot be taught as an independent subject in the initial six years of elementary school. A modest coverage of physics starts at the eighth grade, the second year of middle school, and proceeds spirally along four circles: circle 1 at grades 8 and 9 covers qualitative aspects of physics with minimum application of algebraic equations; circle 2 in senior middle schools repeats most topics in the first circle with more mathematical emphasis; circle 3 contains calculus-based "general physics" in the first one or two years of tertiary education; circle 4 of "theoretical physics" includes advanced topics ranging from classical mechanics to quantum mechanics. The last circle is required for a Bachelors degree in physics (Cheng, 1984; Shi, 1983; Wang, 1994). Hence, the spiral structure begins at the eighth grade in middle schools and ends in the fourth year at most colleges and universities. This structure is further extended at the graduate level by specialties and at the elementary level in an introductory science course named General Knowledge of Nature. The arrangement of the class hours in the elementary and secondary schools is listed in Table 1.

Table 1 inserted around here

Shi (1983) further elaborated the arrangement of physics classes in a semester system:

> All students take physics courses for 1 or 2 hours per week in the second and third years of junior middle school, and for 2 hours per week in each year of senior middle school. Physics classes are not offered as electives but as part of the regular curriculum taken by all middle school students. Every academic year is divided into two semesters (from September to January and from February to July). There are 20 weeks in each semester. Therefore, the students are exposed to more than 500 hours of physics instruction by the end of middle school years. (p. 1011)

This assessment of class hours excludes additional time squeezed into the program schedule by individual schools. For those lectures in secondary physics, around one third is allocated for mechanics, another one third for electro-magnetism, and the remaining lectures cover an introduction to acoustics, heat, optics and atomic physics. Quantum mechanics and special relativity are briefly mentioned in the textbook, and students are not required to use their preliminary knowledge in modern physics for problem solving purposes. Wellington (1992) reported: "It seems (Cleverly 1985) that physics is given a central position in the Chinese curriculum and ranked higher in terms of curriculum time than chemistry and certainly biology at secondary level and above (Allsop 1988, Cross and Price 1991)" (p. 131).

To provide a clear guidance on the national physics curriculum, great care was taken by educators in the syllabus editing. Cheng (1984) reported:

> In the recent reform a draft physics syllabus was produced by a working party comprising teacher-trainers from universities, experienced teachers and the curriculum team in the People's Educational Press. The draft syllabus was then published in the journal Physics Teaching (circulation 110,000 among 300,000 physics teachers) and comments from readers invited (Lei, 1981); comments received were published either in full or as excerpts. On the basis of the hundreds of comments received, the syllabus was redrafted and sent to the relevant institutions for endorsement. Meanwhile the draft was tried out by "correspondents" who are grassroot teachers. These correspondents were selected so that the draft syllabus was taught to pupils of different abilities. The correspondents submitted monthly reports and in many cases the curriculum team members of the People's Education Press, themselves experienced former teachers, went to observe classes where the new syllabus was being tried out. The syllabus was then finalised in a special meeting at which experienced teachers, teacher-trainers and education researchers from all over the country were represented. The final syllabus was rubber-stamped by the Ministry of Education. (p. 116)

The most recent syllabus for a nine-year compulsory education was disseminated by the State Education Commission in 1988. Four goals have been set in this syllabus for school physics

1. Guide students to study preliminary knowledge of physics and its applications, and appreciate important roles physics plays in improving human life, science and technology, as well as constructing socialist society.

2. Enhance students' fundamental capability in observation, experimentation, analysis, synthesis, and simple applications.

3. Stimulate students' interest in physics, and provoke their desire to study physics.

4. Integrate patriotism and dialectical-materialism in physics teaching, and prepare student scientific attitude.

Guided by these goals, contents of the physics syllabus were selected based on four criteria:

1. Cover the most frequently used, basic, and digestible knowledge base.

2. Strengthen the connection between physics knowledge and practice.

3. Design the instruction at an appropriate level of difficulty.

4. Meet the needs of different school systems.

Developed by the best minds in human history, such as Newton and Einstein, physics is a challenging subject to both students and teachers. Several important regulations in physics instruction are discussed in an introductory section of the physics course syllabus. The major part of this discussion is summarized into four points:

1. Improve teachers' guiding role
Teachers' major guiding roles include: stimulating students' learning interest and desire; promoting students' active thinking; creating positive learning conditions; and providing indispensable lectures and individualized tutoring. Teachers should not assign too much homework to over-burden students. The lecture should not be too detailed, and students ought to have enough space to think and act independently. Students' attention should be guided to the focus of knowledge comprehension and

investigation. Teachers are encouraged to understand students' psychological characteristics, and flexibly design instruction according to students' knowledge background and cognitive levels. In addition, appropriate criteria should be set for different students to meet the needs of their academic progress.

2. Strengthen teacher demonstration and student experimentation

Observation and experimentation are the foundation of physics teaching. Through the lab training, students are expected to obtain clear and concrete pictures about physical events. The construction of these pictures is one of the indispensable steps toward an in-depth understanding of physics concepts and laws. Furthermore, observation and experimentation are important in nurturing scientific attitudes and stimulating student learning interest. Observation skills prepared at the junior high school level include: conducting objective oriented observation, catching major characteristics of the phenomena, and observing conditions related to the phenomena change. These student experimental skills should be illustrated through clarifying experimental objectives, correctly using lab equipments, systematically recording scientific data, and faithfully reporting the experimental findings. To achieve these goals, students are encouraged to use their hands and brains, and the lab performance should be evaluated as a part of their school achievement.

3. Teach physics concepts and laws

Physics concepts and laws are important components of physics knowledge. However, at the junior high level, the requirement should not be too high or too strict. Most concepts and laws are summarized at this stage through analyses and syntheses of physical facts. The major skills in this category include distinguishing relevant and irrelevant factors, identifying common features, and extracting concepts and laws.

4. Pay attention to knowledge application

The application requirement is designed to improve physics knowledge comprehension, enhance problem-solving skills, and stimulate learning interests and self-consciousness. Using the simple knowledge of physics, students should be able to explain relevant phenomena, conduct formula calculations, and analyze and solve appropriate exercises problems. These goals can be reached in many ways, including teacher emonstrations, student exercises, and classroom discussions. Teachers are expected to demonstrate the methods of problem solving. Concurrently, students are required to independently explain physics phenomena and propose pertinent approaches to solve simple problems. (State Education Commission, 1988, p. 3-5)

In addition, not all knowledge bases were weighted equally in the physics syllabus.

The importance of physics topics was classified in this syllabus in three strata.

1. Knowledge

Students are required to know key points of the specific knowledge bases, and can find the knowledge applications in physical contexts.

2. Understanding

> Besides those requirements specified at the "knowledge" level, students should understand specific meaning associated with the knowledge, and be able to use it in analyzing and solving simple problems, such as explaining simple physical phenomena, and conducting modest calculations.
> 3. Mastering
> Besides the requirements specified at the "understanding" level, students at the "mastering" level are expected to be quick-witted at problem solving. In addition, lab skill requirements are illustrated by proper experimental operations and correct conclusions. (State Education Commission, 1988; p. 7-8)

These teaching guidelines for compulsory education are consistent with the contents of the most recent secondary physics syllabus developed by the State Education Commission (1986). Besides those aforementioned directions, additional training in abstract thinking, including logic reasoning and mathematical proving, is required at the senior high school level. Technological applications, such as man-made satellites, semi-conductors, lasers, and new energy resources, are also introduced in the secondary physics curriculum. Moreover, high school physics contains advanced topics like mass-energy relations, statistical concepts, the dual wave-particle feature, and other important concepts in modern physics. Swetz (1980) commented: "In the modern Chinese school system, the teaching of physics at the secondary level has traditionally been rigorous" (p. 363).

At the tertiary level, Strassenburg (1983) confirmed: "The academic program for a college physics major is largely predetermined by the Ministry of Education, and varies little from one institution to another" (p. 449). Ten years later, Sun (1993) still maintained: "All courses are based on the physics teaching syllabus that is worked out by the State Educational Committee, but faculty members choose texts and decide on the content of the course. Texts may be those of Chinese scholars or translations of British or American texts (Halıday and Resnick, for instance)" (p. 297). Shi (1983) listed the subjects taught in physics departments at

most universities (Table 2).

Table 2 inserted around here

Inspection of Table 2 shows that most students cannot take elective courses in applied physics until the end of the fourth year. Unlike most physics programs in the West, no transitional Modern Physics class has been set in the Chinese program to ensure a smooth advancement from classical physics to twentieth century physics. Most students are accustomed to the close-ended confirmatory reasoning, and feel more comfortable with classical physics. In most exercises, including the intensive training designed for the college entrance examination, students have been constantly asked to confirm the book answer through hand calculations. Rarely have students met an open-ended question in class. But in modern physics, exploratory approaches are widely employed, and many questions, such as the meaning of the wave function (Ψ), have no closed answer. Thus, most students have to struggle a lot to understand the logic behind quantum mechanics. The situation could have been eased considerably if an intermediate Modern Physics class had been installed in the program. In spite of the pitfall of school physics at tertiary level, Shi (1983) maintained: "At the college level, physics students are usually good at theoretical topics involving quantitative computations, and their competency in mathematics (on the operational level) is quite satisfactory" (p. 1014).

Implementation of the nation-wide spiral curriculum was affected by many factors, including the national college entrance examination, key vs. general school classifications,

urban and rural discrepancies, and the school system articulation. Problems and controversies of physics education have been centered around these factors, and makeshift reforms have been made in China based on several ongoing experiments.

The Ongoing Experiment in Chinese School Physics

China has the largest population in the world. To alleviate conflicts between the limited natural resources and the increasingly challenging educational demands, the national college entrance examination was introduced to select the best students for higher education. Wellington (1992) commented:

> Perhaps one positive result is that Chinese students are not afraid of exams -- they are reared on them. One of my hosts told me that in his province he had even been forced to take an exam to get into primary school. "In China", he told me, "everyone is judged, classified and selected." (p. 133)

In essence, the entrance examination was essentially an expedient experiment upon its introduction. Shortly after the Cultural Revolution, Deng Xiaoping (1978) asserted:

> Of course, we must not put blind faith in examinations and consider them to be the only method for checking on studies. Moreover, conscientious studies and experiments should be made on how to improve the content and the form of examinations to make them more effective. (p. 7)

Several reforms were made to improve the examination. Initially, physics was integrated with chemistry as one subject in the examination. Due to the fact that no national curriculum was implemented in physics education, the first college entrance exam was based on local review guidelines published in each cities, provinces and autonomous regions. In 1978 and 1979, physics was installed as an independent subject in the national examination. However, no national textbooks were employed in physics teaching until the year 1980. Thus, in these two

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years, the examination instrument was developed based on a review guideline from the then-Ministry of Education. Teachers were advised to adopt extra teaching materials to cover topics which were not mentioned in their local textbooks. These supplementary materials were expanded so rapidly that most students were over-burdened by the complicated homework and extra class hours. After adoption of the national unified textbooks, however, various supplementary materials were still employed in many schools, which also caused a substantial overlap between secondary and tertiary physics.

Because the examination has been the only instrument to determine college or university admission, the difficulty levels of the unified tests were adjusted several times to influence school physics instruction. In the late 1980s, item banks were utilized in the test design, and more measurement theories were employed to control test errors. Nevertheless, according to wisdom of experienced Chinese teachers, as long as the tests are required, the best preparation students can get is to solve all kinds of physics questions, especially those similar to the questions appeared in the previous examinations.

Robinson (1992) pointed out: "It is also worthy to recall that China has a long tradition of recognizing and promoting achievement and talent on the basis of examination" (p.189). Walzer (1983) concurred: "For some thirteen centuries, the Chinese government recruited its officials through an intricate system of examinations" (p. 139). At the time the college entrance examination was re-installed by Deng Xiaoping in 1977, the Confucian examination had been abandoned for less than 72 years. Similar to the effect of passing the traditional examination, scoring higher in the current national college entrance examination not only secures one's better life in future, but also promotes social status of the family

Thus, commitment and competition in the examination are not confined to students or within schools. Parents and relatives are automatically involved in the neighborhood competition, and make their best effort to help students pass the examination to save the family face. The fervent competitions inevitably put heavy weight on more difficult school subjects, such as physics. Thus, the burden of physics homework is rooted in in-depth contexts of historical and social background, which are not completely under the government control.

The government has repeatedly criticized the ongoing overheated race for tertiary admission, and recently adopted a set of new reforms to decrease the pressure of the examination. One of the most recent reforms was designed to reduce the number of school subjects in the examination. Since physics was the most difficult subject in secondary education, excluding physics in the examination could substantially alleviate students' burden. This reform was first implemented in Shanghai and Guangdong. Hang (1988) delineated some effects of these trials:

> Physics will not be included this year in the Shanghai examination region, which will chill the initiative of the physics teachers and lower students' enthusiasm as well. Nevertheless, many outstanding students are still expected to enter themselves for a physics department examination -- even the champions of the national Mathematics Olympiad often wish to major in physics. This reflects the fact that Chinese students are very interested in physics. (p.25)

Manos (1992) reported a nation-wide implementation of this reform in the 1990s:

> In 1993 a new national examination will replace the National Entrance Examination that has been in effect since 1977. This new examination will have no penalty for guessing and will serve as a test bank for examples of good questions. The new system has four four-subject examinations, but a student need pass only one battery of four tests to qualify for university admission. The subjects for each battery may be:
> **Liberal Arts**-politics, Chinese, mathematics, foreign language
> **Science and Technology**-physics, Chinese, mathematics, foreign language
> **Medical Science, Agriculture, Forestry**-mathematics, foreign language,

chemistry,biology
Economics, Geography, Geology-Chinese mathematics, foreign language, geography
Physics majors would take the Science and Technology entrance examination. (p. 469-470)

In response to the partial cancellation of physics requirement in the entrance examination, high school physics was taught only to those students who would pursue a major in science and technology. This change has certainly degraded the importance of physics in secondary schools. But, to most outstanding students, physics is still a unique subject in which to invest their intelligence and effort, and eventually many of them are rewarded with better chances to study abroad. Hang (1988) pointed out:

> Furthermore Cuspea (China-US physics examination and application) has strongly inspired students to greater efforts. Cuspea, sponsored by Professor Tsung Dao Lee, the Nobel prize winner, is a plan to send outstanding students to take physics Ph.D.s in the USA. This plan, agreed by our government, involves 70 US universities, through which more than one hundred Chinese students (as well as a few young teachers and researchers) have gone to study in the USA every since 1980. (p. 25)

Hence, the recent reform of Chinese school system has pushed physics education toward serving specialists, rather than general citizens. Shi (1983) was very concerned about this discrepancy:

> In China, where 95% of its middle school graduates do not go on for regular college education, the relevance of their middle school education to their function in society becomes important. In other words, the primary goal of secondary education is not to prepare students for college but for entry into the society. (p. 1014)

Based on the national curriculum, a large number of fundamental concepts have been covered in school physics. Another reform in recent years allows elimination of the entrance examination for a few best students from a small number of key secondary schools. This policy change reflects a fact that for the purpose of measuring student achievement school

grades are more valid and informative than a single student score from the entrance examination. But this new policy has not resulted in a complete cancellation of the exam. In reality, the entrance examination is much easier to monitor, and results are less vulnerable to improper conduct, such as cheating and corruption. Due to the strong competition in the examination, concerns about the test administration are not totally groundless. Since the end of the Cultural Revolution, despite the great care taken by the government in the entrance examination, some officers still dare to risk their power to raise the test scores for their children. In contrast, school grades are determined by ordinary teachers who have little administrative power to resist the score contamination. Thus, the tertiary admission based on school grades could inevitably favor those students from high rank families.

In short, although the Chinese government has proclaimed that "Education should be geared to the needs of modernization, the world and the future" (Deng Xiaoping, 1983; p. 23), the inflexible political system rarely worked adaptively, and societal needs were usually handled on an ad hoc basis. When the government was pushed to select the best students for tertiary education, physics as a challenging subject gained its importance. On the contrary, when there was widespread complaint in the society about the escalating pressure of examinations, deleting the physics test became one of the government's most efficient options to ease the situation.

In spite of these recent complaints and reforms, the national college entrance examination seems to be an indispensable instrument to maintain relatively fair competition in tertiary admission. Shi (1983) observed:

In order to enter college after middle school graduation, it is almost imperative that the

> students enter the best junior middle schools and then the best senior middle schools. Hence those who desire a college education must plan for it in early life. (p.1011)

The best school in a certain region was usually designated as a key school by the government. This recognition was mainly based on the quality of school facilities, teachers, and student academic performance. Limited by the insufficient educational funds, priority of investment was given to a few key schools. Deng Xiaoping (1978) directed:

> In order to speed up the training of qualified personnel and raise the level of education as whole, we must consider the need to concentrate forces and strengthen the key universities and secondary and primary schools so as to raise their level and the quality of teaching as quickly as possible. (p. 12)

Consequently, the enhancement of education in a few key schools was achieved at concurrent sacrifices among general schools. Students admitted in general schools usually had lower academic achievement. Teachers of these schools were encouraged to adopt a set of lower track physics textbooks. In contrast, better teachers and equipment were accumulated in a few key schools to ensure that their students were well educated in every school subject. The rationale behind this special treatment was quite simple: since tertiary admission was determined by the total score of the entrance examination, a higher admission rate could be achieved through accumulating the best teachers and facilities in all subject areas. Following the model of the national key school, local Chinese governments established local key schools at various levels. School physics in this "pagoda" system was inadvertently pushed toward serving a few best students at the top of key schools.

Recently, further reforms have converted many general schools into professional schools. Professional schools are designed to connect secondary education directly with the current job market. Because Chinese secondary education has been largely overshadowed

by the pressure of tertiary admission, many high school graduates were not ready to go to the job market, which in turn forced most of them to re-take the college entrance examination for several years. Meanwhile, the society needs a large number of technicians in various professions. Therefore, professional programs can serve the purpose of reducing the admission pressure and meeting the needs of the society. While the physics curriculum in secondary schools has been well set to support tertiary education, the role of physics remains unclear in most professional schools. Hang (1988) wrote:

> At professional school it is more difficult to produce a single standardised physics course. Electronic technology and electrical engineering are required for some professional schools, including work on electronic devices or vehicle repair, but physics is not required for other professional schools such as medicine and fine arts. So there needs to be much discussion and development if a standardised physics course is to be produced for all professional schools. (p.24-25).

Thus, school physics is facing an ongoing challenge of adaptation in professional schools. In addition, the debate of "science for everyone" vs. "science for scientists" has been heated in secondary education in the 1990s. Physics educators lead the nation in this ongoing reform effort. Pan (1990) reported:

> In order to keep abreast of the social requirements for the knowledge of physics and to treat these requirements as an important basis for determining the teaching content of physics in secondary schools, the China Physics Teaching Society has conducted surveys among sixteen occupations and determined the demand for 132 areas of knowledge in physics. On the basis of these surveys, a plan for restructuring the physics courses in secondary schools has been formulated. The survey results showed the following: of forty-seven physics items that had not been included in textbooks or adequately explained in class, twenty-eight were about electricity, comprising 59.9 percent of the total, whereas ten items were about electrotechnics and electronic technology, accounting for 35.7 percent of the total items about electricity. (p. 54-55)

These survey results were employed by physics educators in developing a new physics curriculum for an alternative 5-4-3 school system. The 5-4-3 system was a pilot program first

implemented in the Second Middle School affiliated with Beijing Normal University, which includes a 5-year elementary school, a 4-year junior middle school, and a 3-year senior middle school. Compared to the traditional 6-3-3 system, this new program moved one year of education from the elementary to junior middle school level. Thus, students in the 5-4-3 system have one extra year in the junior middle school to study more contents in school physics and other subjects. Currently, this new system has been implemented parallel to the traditional 6-3-3 system. However, under the pressure of tertiary examinations, it remains to be seen whether physics education in the 5-4-3 system will be inadvertently pushed toward an expert-oriented direction.

At the tertiary level, recent reform was introduced to change the nation-wide student job allocation system, a government program imported from Russia. In this system, students at the tertiary level were guaranteed a public job from the government after graduation. During the 1950s, only a small number of intellectuals in China experienced tertiary education, and the job allocation system was established to fully utilize the wisdom of these college or university graduates. In recent years, however, the shortage of tertiary graduates was alleviated considerably. Liu and Jia (1994) even predicted that many of the Chinese university graduates would not be needed by the economy in year 1995! Hence, it is difficult to find enough attractive jobs for those graduates. Zhang (1994) cautioned:

> For a long time, all college graduates were guaranteed jobs by the state upon graduation. In spite of some reform in recent years, the problem has not been resolved in any fundamental way. All qualified graduates who were admitted to a college or university for education under the state plan are still assigned jobs by the state upon graduation. Therefore, the phenomenon of the "big pot of rice" in the job assignment system, and the "iron rice bowl" syndrome in the human resources system, still exist. (p. 69)

The job assignment at tertiary level also presents a sharp contrast to various unappealing job allocation programs for middle school graduates. Deng Xiaoping (1978) cautioned: "We encourage everyone to strive for progress, but progress depends, after all, on whether the individual makes the effort" (p. 9). Due to the inequitable opportunity of employment between secondary and tertiary graduates, many secondary students studied day and night to earn college admission. But once they are admitted to tertiary education, their future jobs are assured, and little pressure exists to push them to study hard. Even Zhu Kaixuan, the current Chairman of the State Education Commission, had to acknowledge "that university students do not feel much pressure or incentive to excel" (Jacobson, 1987; p. A40). In a recent announcement of the reform plan, Zhu Kaixuan (1994) explained:

> This new plan, known as the "Mid-term Reform Plan" was first tested in colleges and universities in Guangdong Province. In March 1989, the State Department endorsed this plan. Since then, some colleges and universities announced this plan to students who were newly admitted to their campuses. It is expected by the State Education Commission that in the next few years this mid-term plan will be implemented by most of the colleges and universities. (p. 19)

Corresponding to the ongoing system change, a new challenge to physics education is a further reform of the existing curricula to meet the needs of the job market. One approach most physics departments have taken is to strengthen technological elements in the undergraduate program. In the traditional program modeled after Russia, application oriented courses, such as electrical engineering and electronic technology, were treated as minor subjects in physics departments, and yielded in importance to major courses, such as classical mechanics, electrodynamics, statistical physics, and quantum mechanics. The pitfall of the old inflexible structure was obvious: regardless how hard a student studied, no one could

reach the frontier of physics in three or four years. Besides, the knowledge base acquired through the tedious course work was still irrelevant to the needs of most employers. In the modern market economy, most students are required to pass an employment examination before signing a job contract. Thus, a broader knowledge base is needed to enhance students' job compatibility.

As an adaptive measure, many universities added more elective courses in application oriented physics. Zhang (1994) shared information about the recent reform at Nanjing University:

> In order to ensure that the science students whom we educate will be more adapted to and compatible with the needs of the hiring units and departments, our university chose a number of programs and departments to be linked with departments of practical application outside the university, thus carrying out a cooperative education model. ... This model known as "3.5 + .5" allows students to study at school for three and one-half years and then work in factories for half a year. ... The implementation of the system of cooperative education not only has made it imperative for students to come to a better understanding of society, as well as the state of national affairs, but also forces an integration between the knowledge students learn from books with the realities and practicalities of industrial production. At the same time, the industries also combine education (teaching and learning) with research and with product development. Industries will discover the characteristics of personnel trained in the sciences, and can enlist specialized technologically trained personnel from these students on the basis of merit. (p. 63-64)

Positive results of this ongoing experiment at Nanjing University have been disseminated to the public, and physics departments nation-wide are expected to follow suit (Hayhoe, 1993). In terms of job orientation, Zhu Kaixuan (1994) pointed out: "We also encourage students with humanity majors and science majors to teach in public schools or work in practical units" (p. 21). Hence, teacher training has maintained its priority position in the recent reform of tertiary graduate outlet.

Unlike common practice in the West, physics teachers in China are not trained in education departments, but rather in physics departments. Although a few courses in pedagogy, psychology, and teaching methods are offered at normal universities, student teaching usually lasts for a month with a couple of pre-service lectures and several informal discussions with in-service teachers. Thus, the teacher preparation programs in China are more focused on subject-matter training. Parker and Parker (1986) reported:

> Standard qualifications for teaching at the three lower school levels are: (1) to teach in kindergarten or primary school, a middle school graduate must complete a three-year secondary teacher training program; (2) to teach in a junior middle school, a senior middle school graduate must complete a two-year teacher training program; and (3) to teach in senior middle schools, senior middle school graduate must complete a four-year higher teacher training program. (p. xli-xlii)

These standards are set for all school subjects in general. But in physics, the standard appears to be a little too restrictive. Based on the program structure in tertiary education (Table 2), physics teachers in middle schools are required to take courses in "general physics", and high school teachers must have courses in classical mechanics, electrodynamics, statistical physics, and quantum mechanics. These standards are in line with a well-known proverb in China, "To give a bowl of water, one needs a pool of water". In reality, however, these standards are too high to reach even according to the criteria set for physics teaching credentials in most developed countries. As far as the teaching is concerned, a two-year teacher training in calculus-based physics should be sufficient to teach high school physics, and the general standards designed for all subjects may have disqualified many competent teachers from teaching and intensified the shortage of physics teachers at high schools. Manos (1990) pointed out

> In the 1950s, to speed up the teacher training process, China had established short-cycle, two-year junior teacher colleges to meet the demand for teachers. Most high school physics teachers in China were trained at these short-cycle schools (Shen & Zhao, 1986). The need for better qualified teachers in China is clear, and there is an effort among Chinese educators to draw more high school teachers from the four-year normal universities. However, as long as a severe teacher shortage exists, the need will be met by the two-year institutions. (p. 15)

It should be noted that the majority of courses in the third, fourth, and fifth year programs are related to theoretical physics, and the course differences between normal universities and comprehensive universities are not significant (Shi, 1983; Sun, 1993). Because of the irrelevancy of theoretical physics to secondary teaching, graduates from normal universities have to either let this knowledge become rusty or refresh it for a different purpose, such as pursuing a graduate degree in physics. In contrast, teachers trained through the two year program are not only as competent, but more settled in a teaching position.

A seeming counter-example to the over-qualification argument is the fact that after practicing in classrooms for a couple of years, many teachers who graduated from comprehensive universities are doing a better job than those who graduated from normal universities. Since comprehensive universities require slightly more courses in physics, it appears that more knowledge, regardless how irrelevant it is to the job, still has a profound contribution to the secondary physics instruction. An overlooked factor in this example, however, is the dramatic difference in student quality. In China, Parker and Parker (1986) observed: "Talented youths still show little interest in teaching" (p. xlii). The government has been offering extra incentives, including reduced cost of accommodation and gracious key university statuses, to attract more students into normal universities. But most students who passed the challenging national entrance examination want a job better than a secondary

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teaching position. Deng (1995) recalled: "According to figures from 1992 taken from 12 careers available to most Chinese, teaching salaries were higher only than those for farming, forestry, animal husbandry, fishing and water conservation" (p. 13-14). The lower social status affected the teaching profession in all subject areas. Thus, this counter-example could be a result of the student quality in general, rather than the additional subject-matter training in theoretical physics.

The requirement of theoretical physics is largely caused by the inflexible structure of the school system in which physics teachers are trained in physics departments. This structure also undermines graduate programs in physics education. Since establishment of a Masters program in physics education in 1984, more theoretical physics courses have been included in the degree requirement, and the program was hammered to take a shape more like other graduate programs in theoretical or experimental physics. For instance, Master students majoring in secondary education are required to take advanced quantum mechanics at Beijing Normal University. A parallel requirement exists in similar programs at other universities. These irrelevant requirements are no doubt an extra burden to those students majoring in secondary education. However, in terms of the strict criteria developed for most physics majors, the Masters program in physics education still appears to be too "soft" in many respects, and no doctoral program has yet been approved to enhance research in physics education. Thus, most ongoing teaching experiments are conducted by inservice educators, including physics teachers in secondary schools and university or college professors whose job is to supervise student teaching and prepare lectures for the teaching method classes. In general, much of the research has remained at an empirical level, and many important

approaches adopted in the West, such as the learning cycle, hand-on science, and cooperative learning, have not been systematically tried in Chinese schools. Graduate students who have obtained a Master's degree in physics education have to pursue further education in the West, and the rate of successful admission has been quite low. Schmuckler, Wei and Zheng (1990) admitted:

> Financing students from China, especially in science education, is a challenge. Though students who pursue degrees in the natural sciences can usually obtain financial assistance as teaching or research assistants, funding is generally not available for study in science education. The lack of funding is a serious problem for science educators who wish to enroll foreign students in graduate programs. (p. 80)

Furthermore, among the small number of science educators trained in the west, few would go back to China due to the current restrictions in program development, economic insufficiency, and political freedom. Hence, physics educators in China still need to conduct major research at home and enhance their communications with the West to speed up the modernization process in Chinese schools. Recently, physics educators across the nation, especially those in Beijing Normal University and Eastern China Normal University, have been vigorously exploring possibilities to develop a doctoral program in physics education. It is expected that this ongoing effort will promote the status of physics educators and enhance the quality of research in physics education.

In summary, diversity of secondary school physics has been reflected over different school types and systems. Key, general, and professional schools are three school types co-existing in contemporary China. Elementary and secondary schools are structured in either a 5-4-3 or a 6-3-3 system. A more fundamental issue behind the school structure hinges on the conflict between limited natural resources and the largest world population in China. At

the tertiary level, major experiments have been centered around the job allocation system and physics teacher training programs. While secondary physics was seriously affected by the tertiary entrance examination, the role of physics in professional schools is yet to be further clarified. Factors driving these ongoing reforms are deeply rooted in Chinese historical, social, economical, and political contexts. Thus, contextual analyses are needed to elaborate problems and controversies concerning school physics in China.

Problems and Controversies of Chinese Physics Education

Since the introduction of a market economy in the Deng Xiaoping era, the job market for high school graduates has been quite unstable, and most students do not wait for government assigned employment, but rather pursue tertiary education to secure a better future. Thus, many students chose to participate in the entrance examination for several years. This practice was supported by the Chinese government upon introduction of the entrance examination. Shortly after the Cultural Revolution, Deng Xiaoping (1978) directed: "We must encourage and help students who have not done well in their examinations to continue the effort and not to worry needlessly about them" (p. 7). Except for health related reasons, most students are eligible to take the exam repeatedly until age 25. As more high school graduates were left out of tertiary education and entered in the pool of college candidates each year, the pressure on the entrance examination steadily escalated. Consequently, many teenage students have little time for other activities, including physical exercise, and some of them must wear glasses before high school graduation.

For those who passed the college entrance examination through several years of

repetition, their styles of thinking are quite different from their classmates who passed the exam on the first try. Thus, an orientation on learning methods is much needed in college physics classes to improve students' reasoning skills. Although this articulation problem has been identified at tertiary level, the heterogeneous student population was essentially one of the inevitable side effects resulting from the entrance examination.

The entrance examination has also skewed the emphasis of physics education at secondary level because of the inability to test laboratory experience in paper-pencil format. So far, no alternative assessment, such as laboratory operations, has been found feasible for an exam taken by millions of high school graduates. Therefore, only a small portion of the test score was allocated to the experimental section of the national entrance examination. These test items usually involve drawing certain lines in an experimental design or explaining certain phenomena from an experiment, all of which can be taught without time-consuming lab instruction. In addition, many schools do not have a well equipped laboratory, and thus, little emphasis can be placed upon the much needed experimental training. Instead, students are taught strategies to cope with the paper-pencil experiments modeled after those real test items. Manos (1990) reported:

> Competition for passing university entrance examinations is so high, and there is so much emphasis on passing the university entrance examinations, very little laboratory is taught (Manos, 1988). This seems contradictory for teaching physics, a laboratory science. (p. 17)

Even though all effort is being made in recent reforms to integrate more test items in experiment, no solution is in sight for changing the paper-pencil format and directing teachers' attention to the enrichment of students' lab experiences in secondary education. Li (1991)

observed:

> In many middle schools, physics teachers give students a lot of physics problems and teach them how these problems can be solved. These teachers want to give their students the kinds of physics problems they may encounter in the national qualified examination of physics, held once a year in China. The teachers hope their students can pass this examination. But the students are forced to do so many physics problems that they cannot think carefully. Another defect of such tactics is neglect of experimentation in physics. Some teachers have transformed vivid, experimental physics into dull calculation. (p. 233)

Driven by the entrance examination, an in-depth understanding of specific physics concepts has not been pursued persistently in secondary physics education. In the real examination, limited by the amount of testing time, many important physics topics cannot be sufficiently reflected in the entrance examination. To extend the coverage, several topics must be combined into a single question, and thus, the emphasis has been shifted toward the important concept connections. Much of the homework is characterized by its confirmatory feature, and few students are encouraged to think in terms of knowledge exploration. In the end, students were forced to memorize mathematical relations among several theorems and formulae without an appropriate appreciation about the historical contexts of the evolution of physics.

Moreover, the national college entrance examination cannot guarantee equal quality of education across the country. Because of differences in economic development and educational investment among different geographical regions, different tertiary admission scores have been set by the central government. Typically, the admission scores were reduced for two kinds of regions, remote provinces in the western part of the country and large cities, such as Beijing, Tianjin, and Shanghai.

Due to the inferior educational conditions in the remote provinces, students encounter substantial difficulties in scoring higher in physics in the entrance examination. Thus, a lower admission score is needed to enroll more students from these regions in tertiary education. But the increase in tertiary enrollment cannot automatically facilitate the development in remote provinces. In essence, regional development depends on the number of students returning to these provinces after tertiary education. Without an effective policy to secure students' return, the special admission treatment has essentially helped more brilliant students to leave these regions, and thus, enlarged the inequity of school education across the country.

Meanwhile, the special admission policy for the large cities was designed to enhance the social stability and economic development in these population-condensed urban areas. But as the Chinese economy kept growing, many farm workers from the neighboring provinces flooded into the large cities to search for better jobs. Children of these families are permitted to attend the urban elementary and secondary schools. In spite of the fact that these students were taught in the same classroom along with other urban children, their entrance to tertiary education was based on a much higher admission score designed for their original provinces. This discrimination of students' achievement according to their residential status demanded more studying effort from the rural children, especially in a difficult subject like physics. Thus, under the current government policy, the challenging physics test actually served the purpose of depriving the ex-farmers' children of tertiary education rights. As urban life increasingly depends on the quality services provided by the ex-farm workers, continued discrimination in tertiary admission could undermine the stability of urban society. In each province, on the contrary, urban and rural school graduates are evaluated by the

same tertiary admission score. Because urban children usually have relatively better teachers and equipment, most rural students cannot compete on the uneven ground. Aside from college admission, school physics seems less useful for other purposes. Due to the lack of industrialization, much of the farm work is quite labor intensive, and many rural parents need students' help to lift their living standards. The lack of equity plus the attractive financial benefit has lured some parents to have their children drop out of school. Jacobson (1987) confirmed: "Indeed, one of the widely acknowledged education problems now confronting the country in a period of agricultural progress is the reluctance of rural families to let their children go to school instead of working to bring in more money" (p. A40).

An ameliorating measure in physics education is to have two curriculum tracks at secondary level. The higher track is developed for schools with better equipment and teachers while the lower track covers more basic and practical components in physics. Educators supporting the tracking system argue that it is very difficult to teach physics in rural areas with the same textbooks used in key schools. The differentiation of textbooks not only reflects individual differences, but also matches the classification between key and general schools. But others, including many parents and administrators, are more concerned about the legitimization of inequity in physics education, which could impose damage to students' self-esteem and teachers' self-efficacy at lower track schools. To date, the equity debate remains inconclusive in Chinese society.

Another issue pertinent to the current program reform is the content overlap between physics and chemistry classes in middle schools. For instance, knowledge of atomic structure is taught in both physics and chemistry with similar homework exercises. This inefficient and

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inflexible program structure was modeled after Russia's in 1950s. The necessity of this treatment seems dubious since not all industrialized countries separate physics and chemistry in junior middle schools. Solutions to the content overlap could be pursued through an integration of physics and chemistry in middle schools. But in reality, most physics teachers were trained in physics departments, and felt less comfortable teaching non-physics concepts in an integral science class. Wellington (1992) observed: "No concession appears to be made towards integrated or coordinated science" (p. 131). Because a whole generation of Chinese students have gone through the existing program, the society is somewhat accustomed to the separated physics and chemistry subjects in middle schools. On the other hand, Deng Xiaoping's modernization drive has made Japan the largest economic partner of China. The influence of Japanese integral sciences has provoked the ongoing debate about the current system. Pan (1990) described:

> There are three differing opinions in the ongoing heated debate regarding the necessity of offering integral science courses. Those in favor believe that the individual academic science courses should be developed into practical integral courses for training qualified citizens. This change is also viewed as being necessary to instruct students on entering into social life rather than merely seeking to enter higher-level schools. Considering that pupils are at the stage of changing from imaginary to logical thinking, the courses should not be offered as they would be to adults. From the viewpoint of integrating science into the lives of citizens, it is appropriate to offer integral science courses. (p. 57)
>
> As for the supporters of individual science courses, they maintain that each subject has its own characteristics and that these varying characteristics reflect the different scientific methods. The individual science courses are advantageous to juniorsecondary students in laying a foundation for a comprehensive training in the sciences. (p. 57)
>
> A third opinion is expressed by those who maintain that individual science courses have their drawbacks whereas integral science courses have their points. These people believe that the integral science courses should neither be popularized blindly nor rashly denied. It is evident that the debate on this issue will influence curriculum development. (p. 58)

As long as the issue remains in debate and no action is taken, the third opinion continues to have the upper hand. This situation appears to reflect the social "inertial effect" which keeps school physics in its original status. In addition, articulation among different levels of the spiral curriculum also impedes the narrow-focused revision of physics in middle schools.

Methods of teaching is another hotly debated topic for a long time. In 1985, a then Vice-Premier, Wan Li, decried the traditional methods of teaching:

> China's outmoded and traditional educational concepts and teaching methods are closed educational concepts and teaching methods. Educational material is usually fixed and ossified and the task of education is just to instill it into the student's mind. People are not allowed to express their own views or ask why, let alone show doubt about what is taught. In examinations, students are to answer according to precisely what they have been told and in a fixed form, so as to receive a high grade. People brought up under such educational concepts and teaching methods are bookish and will do what they are told, and will certainly lack creativity and initiative. (K8)

Stollberg (1980) concurred:

> Most of the teaching is heavily teacher-dominated, with students diligently taking notes, complete and very neat. Class discussions do not seem to be highly encouraged. The physics and mathematics seem to be somewhat above the typical level of U.S. high schools in these subjects, but there is more emphasis on facts and principals and less on the broad understandings and applications our school might provide. (p. 255)

The reasons behind the current method of teaching are many. Among them, Wang (1993) noted:

> Students observe strict classroom discipline, seldom interrupt the instructor, and will resolve a question after class or discuss it with other students rather than ask the instructor. They would be embarrassed to ask a question in class that their peers knew how to solve. (p. 438)

Cross and Price (1988) pointed out another reason:

> Ironically, the restoration of "respect for the teacher" after the disorder of the Cultural Revolution has probably also restored that aspect of "face saving" which

> forbids the student to threaten a teacher's "face" by asking a question. Either the teacher might not be able to answer and thus lose face, or the question might indicate a lack of skill in imparting knowledge on the part of the teacher, a similar "face-losing" situation. It does seem that teachers and students are locked together in a tradition from which it is very hard to escape. (p. 367)

Shi (1983) provided a different explanation:

> The instructor usually prepares immaculately detailed lecture notes before class which are then transferred to the students at a steady pace by writing them onto the blackboard accompanied by verbal explanations. Students are kept busy in copying the written material. Instructors seldom make mistakes in classes. To do so would invite criticism from students who automatically associate mistakes with poor preparation on the instructor's part. This type of student criticism may be brought to the attention of school administration and reflects poorly on the instructor. (p. 1014)

Wang (1994) added:

> The advantage of this structured method is that students get a good deal of information in a limited time. The shortcoming, however, is lack of student involvement and neglect of differences in intelligence and needs among the students. (p. 438)

In reality, although it is fashionable to argue for a change in the current way of teaching, alterative methods, such as cooperative learning, seminar discussion, and individualized instruction, are much more time consuming. In an important subject like physics, students are pushed to possess a large body of knowledge for the college entrance exam. Lin (1993) reported: "Given that most schools are under intense pressure to obtain a high admission rate for their students to colleges and universities, rote learning is still very popular and practical for mastering large amounts of information" (p. 99). Accordingly, replacement of the traditional teaching methods depends on further reform of the elite school system.

The present system has experienced dramatic historical evolution, and debates on further changes hinge on the development of Chinese economy and politics. As China heads

toward the post-Deng Xiaoping era, can the future government increase its investment in education? Would students studying physics refrain from conflicting with the government politics? These two questions are especially pertinent to physics education. Compared to the extreme shortage of lab equipment and physics teachers, students' political reactions have caused no less concern in the global physics society. Fang (1990) recollected:

> Indeed, in the last 40 years in China, physics students have been deeply involved in all movement for pursuing democracy and freedom, and have also suffered heavily from political persecution. Among the 21 most wanted students of Tiananmen, six are from physics departments. In the 1950s, physics students, more than any others, were subjected to hard labor in the so-called "anti-rightist" campaign. (p. 809)

In tertiary education, ideological controversies were concentrated on the "guiding role" of natural dialectics, a branch of Marxist philosophy. William (1990) observed: "Beyond the commonly accepted need to revise the scientific content of Marxist philosophy, however, lay more prickly questions about the limits of its authority" (p. 468). He further reported:

> The "guiding role" debate itself continued to grow, with such prominent figures as Zha Ruqiang and particle physicist He Zuoxiu supporting an active "guiding role", and Xu Liangying, director of the CAS Institute for the History of Natural Science and translator of Einstein into Chinese, opposing it. By 1986 the debate had spilled out of academic confines into the pages of Guangming Daily and Red Flag. (William, 1990; p. 470)

The debate was eventually silenced by the government after the Tiananmen Square event, but discontent in the physics society stays high. Because of the previous political struggles and losses, no consensus has been established in the physics education community regarding the appropriate advice to students. Under the fast-growing market economy, it is also unclear whether physics students will continue to carry on the ideological debate and lead the future political movement in Chinese society.

In summary, due to the effort of physics educators in the twentieth century, school physics has been naturalized in China, and has become an increasingly important subject in Chinese education. Physics instruction is currently driven at the secondary level by the college entrance examination and at the tertiary level by the market economy. Ongoing experiments are guided by societal needs and the government's policy in education. Problems and controversies are deeply rooted in economic, cultural, political, and social contexts, and solutions largely hinge upon political and economic developments in the forthcoming post-Deng era. Hence, time appears to be another special platform that harbors these problems and controversies in contemporary China. Cross and Price (1987) pointed out:

> China is a particularly apt choice for study. With major contributions to world technology and pre-modern science over more than two and a half millennia her history commands attention. Today her 1.2 billion people are being urged to modernise through selected borrowing of foreign high technology. Changes which occurred over some two hundred years elsewhere are being compressed into a few decades. (p. 29)

According to Reardon-Anderson (1991), research in Chinese science education has been rare and difficult. Reardon-Anderson (1991) pointed out "that whereas almost everyone agrees that science is an essential feature of modernity, almost no one has written about the development of science in so-called 'modernizing' non-Western societies" (p. xviii). He further noted:

> China, despite the attention it has attracted, is no exception. In fact, this irony is easy to explain. Scholars who have spent years learning esoteric languages and the intricacies of strange cultures have no time or energy left for the equally forbidding world of science, and vice versa. Some people study China, some study science, but few have the stomach for both. (Reardon-Anderson, 1991, p. xviii)

In this article, only the evolution of Chinese school physics, a branch of the modern sciences, was briefly reviewed, and the coverage of current situation, ongoing experiment, and existing problems may be less than comprehensive in many respects. But since no in-depth account of the Chinese physics education exists in the current research literature, this report represents a modest effort to generate more fruitful discussions among science educators around the world.

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Table 1: Physics Class Hours in Chinese Schools

School Level	Grades 1	2	3	4	5	6	Total Class Hours
Elementary School (General Knowledge of Nature)				2	2	2	204
Junior High School		2	3				156
Senior High School	4	3	4				344

Table 2: Subjects Taught in Physics Department at Most Universities

Grade	Fall Semester	Spring Semester
First Year	General Physics: Mechanics with lab	General Physics: Acoustics and heat with lab
Second Year	General Physics: Electro-magnetism with lab	General Physics: Optics/ atomic physics with lab
Third Year	Classical Mechanics Mathematical Physics Methods	Electrodynamics and Special Relativity Advanced Physics Lab
Fourth Year	Statistical Physics Quantum Mechanics	Quantum Mechanics Advanced Physics (Elective)
Fifth Year	Advanced Physics (Elective) Thesis	Advanced Physics (Elective) Thesis